Transversely polarized Timelike Compton Scattering using NPS/CPS (PR-12-18-005)

Status and plans

(edited after meeting slide 12 to 15 - comments in red)

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Outline

1) Summary of the proposal as of 2018: motivations, setup, projections

2) Recent updates on proton tracking, new solutions

3) PAC: reports, questions, main points to address

4) Status

5) Plans and needs

Context: conditionaly approved experiment in 2018 (C2), several points need to be addressed prior new submission to the PAC
Timelike Compton Scattering

\[ \gamma P \rightarrow e^+ e^- P' = GPDs + Bethe-Heitler \]

Accessing Generalized Parton Distributions (GPDs)

TCS off the proton: 4 chiral-even GPDs at leading twist (H, E, \(\bar{H}\), \(\bar{E}\))

⇒ correlation between quark momentum and its transverse distribution

⇒ nucleon tomography, spin composition through sum rules...

⇒ one of the (assumed) universal quantity that describe the partonic structure of the nucleon
Why measuring Timelike Compton Scattering off transversely polarized proton?

**Timelike Compton Scattering (TCS)**

\[ \gamma P \rightarrow \gamma^* (q') P' \rightarrow e^+ e^- P' \]

\( q^2 = 0 \) and \( q'^2 > 0 \)

**Deeply Virtual Compton Scattering (DVCS)**

\[ e P \rightarrow \gamma^* (q) P' \rightarrow e' P' \gamma \]

\( q^2 < 0 \) and \( q'^2 = 0 \)

TCS and DVCS amplitudes are complex conjugate at leading twist, LO. Access same functions and same GPDs with two of the cleanest processes (only one non perturbative part)

⇒ **GPDs universality studies**, comparing GPDs extracted from DVCS and TCS independently

Need of a certain number of independent observables for extraction by fits of specific functions

⇒ Transverse spin asymmetry or cross section difference: access GPD \( E \) (Im \( \xi \)): indirect access to **partons angular momenta** \( L^g \) (Ji sum rule)

Bring new constraint on GPDs, more difficult with DVCS due to transverse polarized target
Proposed setup in Hall C

Compact Photon Source

Transversely polarized target

Calorimeters

Hodoscopes (as proposed) + 3 layers of GEM

Phonon beam:
2.5 μA e⁻ beam → 1.5 x 10^{12} γ/s at ~75% average circular photon polarization rate for E_{γ} > 7.5 GeV

Target: $^{15}$NH₃, acceptance ±17° horizontal, ±(6°-21°) vertical
~ 0.4 polarization dilution factor for selected events (recoil detected, subtraction of scattering off N or He)
Proposed setup: detection of $e^+ e^- P$

Updated configuration

- 2116 blocks total, active area 0.74 m²
- Vertical aperture $\theta = \pm 1.6^\circ$ (high radiation)
- Calorimeters for electron pair
- Proposed: hodoscopes for the proton
- Now: 3 layers of GEM + hodoscopes
- The beam pipe is not included in simulations currently

Trigger, DAQ

- Momentum thresholds: $p(e^-) + p(e^+) > 5$ GeV, 2D cuts on E and P
- Triple coincidence and missing mass requirements
Updates: proton tracking and background rates

GEM trackers
- Like COMPASS GEM detectors (F. Sauli, NIMA 805 (2016) 2-24)
- 3 mm drift region (70% Ar, 30% CO2, ρ= 1.7 mg/cm³)
- Hit signal: energy deposition in drift region
  Hodo-s, 5 cm thick plastic, passive (no signal)

from Vardan's
01/16/2020
presentation

GEM Tracker rates

Beam background [MHz/cm²], UVA trans. pol. target, signal > 0 p.e., layer 2.

Tracker 1

Tracker 0

Tracker 2

Tracker 3

Rate ~1-2 MHz/cm² at centers (can tolerate >10⁶ Hz/mm² [PDG])
Similar pattern for layers 1 and 3
Updates: calorimeters background rates

Beam background [MHz], UVA trans. pol. target, signal > 0 p.e. (upstream view)

Calorimeter rates

from Vardan's 01/16/2020 presentation

Rate ~60 – 80 MHz at centers
Reconstruction and analysis (e⁺e⁻P)

Proposal:
Threshold at analysis level:
E(e⁺) > 0.7 GeV, E(e⁺+e⁻) > 5 GeV, p(P) > 0.1 GeV

Exclusivity cuts: tagging of e⁺e⁻P, ΔM², Δφ, ΔP⊥

Angular cuts θ, φ for physics and rates:
integrated between BH peaks and/or [40°, 140°]

selected bin for projections
4<Q'²<7 GeV², .15<ξ<.22, .2<-t<.35 GeV²

Bins: 8 (Q'², ξ, t) bins, 16 φ bins, 16 φ⊥ bins,
7.5 <E<11 GeV, 4<Q'²<9 GeV²

New version of analysis: extended phase space
-t up to 2 GeV², 5.5<Eγ<11 GeV
possible studies at lower Q'²
⇒ will not be the main of the physics, studies in progress to see what we can get out of extended range

New generator version include part of radiative corrections and some background channels
$A_{UT}$ versus $\varphi_S$: experimental errors and model dependence

Error bars on first moment fit $A^* \sin(\varphi - \varphi_S)$ for 8 $\varphi_S$ bins and one ($\xi$, $t$, $Q'^2$) bin versus models

$t = 0.25$ GeV$^2$; $\xi = 0.18$, $Q'^2 = 5$ GeV$^2$, $30^\circ < \theta < 150^\circ$, 16*16 bins in $\varphi$ & $\varphi_S$. Model: VGG, various parametrizations

- Uncertainties on moment scaled to theory curves, using 43% target dilution, 90% polarization
- Small asymmetries case of "red" scenario using H+H̃ in event generator used for the proposal

$\varphi_S = 11.25^\circ$

$\varphi_S = 33.75^\circ$

$\varphi_S = 56.25^\circ$

$\varphi_S = 78.75^\circ$

$\varphi_S = 101.25^\circ$

$\varphi_S = 123.75^\circ$

$\varphi_S = 146.25^\circ$

$\varphi_S = 168.75^\circ$

$\Rightarrow$ discriminate models

$\Rightarrow$ quark angular momenta

$A_{UT}$ orthogonal 2 by 2: simultaneous fits, reduce error
Updates: 8 parameters fits of CFFs from realistic DVCS or TCS projections

- 6 independent observables: unpolarized $\sigma$, beam polarized, L target (single and double A), $\perp$ target

- Similar sensitivities (horizontal scale) on DVCS and TCS with 6 independent observables, possibility to extract all CFFs despite under-constrained problem [compare first 2 graphs]
  NB: no experiment yet with all these observables, except for HERMES results on DVCS

- Combining first 2 graphs = 3d graph. Ideal situation, but for future

- Last graph: what could be achieved with current DVCS and this TCS experiments + extensions
  NB: assume GPDs universality and knowledge of higher twist contributions

- Impact of mass and $\Delta$ term (not full twist 3 & 4): evaluated 1% on Im(CFF), 10% on Re(CFF)

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more in CPS talk of 02/04/2020
* Scintillator hodoscopes (proton)
  - High rates ~100 MHz, need to go down by one or two order of magnitude
    → other kind of detector? (faster, thin layers, reduce paddle size…)
  - Proton PID: method to improve (depends on detector choice)

* Trigger
  - High rates, high random coincidence background → need estimation
  - Providing rates for the coincidence trigger

* Photon beam
  - Reduction to higher energy photon? → implied modifications at the level of CPS

* Calorimeters
  - Calibration and readout threshold as for PrimEx not feasible; pion rejection needs momentum determination → need to propose a method with potential setup modifications (GEM trackers…)

* Target:
  - low acceptance at larger -t → new target with larger aperture?
  - Depolarization → provide details on functionality / test results of rotating system
  - Interference between target and CPS field
PR 12-18-005: theory report and PAC members concerns on analysis

* **DAQ**
  - develop software, provide schematics

* **Higher twist corrections**
  - impact of higher twist corrections in universality studies
  → no published results, studies exist

* **Background from N protons and exclusivity**
  - full background simulations needed \((\pi^+\pi^-, \pi^0...)\)
  - resolutions
  → exclusivity studies: need to add all background channels
  → Measurement off N and off unpolarized NH3 additional time

* **Observables**
  - realistic uncertainties on extracted CFFs
  - 2D fits and projections to update final uncertainties on experimental projections

* **Complementarity with other DVCS/TCS experiments, physics impact**
  - improve physics case with broad context and what can be achieve with and without this exp.
  - impact for GPDs universality and extraction
Most urgent needs (in order) and status

1) Solution for reduction of rates and recoil detection
   - changing configuration of hodoscopes
   - additional GEM trackers for proton PID: vertex and momenta

2) Proton tracking in simulations
   - improved tracking and magnetic field to be included in analysis,
     update projection (degradation of resolution/exclusivity?)

3) Trigger
   - rates estimation: random + coincidence

4) Background
   - develop generator for hard exclusive \(\pi^+\pi^-\) and \(e^-e^-\pi^0\)

5) Target
   - study interference of magnetic field target / CPS
   - details+results showing that it will not heat/depolarize, systematics
   - proposed design details / update days for operations

6) Theory
   - impact of higher twist on universality studies, errors
   - include DVCS results and comparison what TCS brings

7) DAQ
   - schematics, needed electronics

Status

comment source: ITAC

- Work in progress
- Added to simulations, reduce rates to \(\sim 30\) MHz. Need external advice

Rolf, Anna Martin

To be done

PAC, Marie

Old work need updates, ideally independent theory input

Comparison done, will update

PR12-18-005_PHY

To be done
Most urgent needs (in order) and status

7) Calorimeters
   - show method for calibration ........................................ ITAC ........................ Work in progress
   - better estimation of low energy $\pi^+\pi^-$ rejection .......... PAC ........................ To be done

8) Background from proton resonances ................................ PAC ................................ To be done ideally

9) Observables
   - show 2D maps and fit result projection instead of combining 1D projections (for final uncertainty) .................... Anna Martin, Marie

10) Updated number of days
    - days of operation: target, installation, commissioning… ....................................................... ITAC, Marie ........................ critical but will be at the end

11) Improved projections, analysis...
    - radiative corrections, different models, other backgrounds...
    - enhanced phase space, double asymmetries...
    - Marie (if time) .................................................. Mostly done

12) Additions
    - running time off unpolarized NH$_3$ and N (background, systematics) ...................................... Anna Martin and us ........................ Projections can be done quickly, same setup except for target part: section about N target

Status

- Mostly done
- Mostly done but may dilute the message (may not include)
- To be done
- To be done ideally
- To be done, not essential
- Work in progress